

DRAFT

RECOVERY PLAN FOR Haplostachys haplostachya
and Stenogyne angustifolia

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This is an agency and public review draft of the recovery plan for Haplostachys haplostachya and Stenogyne angustifolia. It is not an official government document. It has not been approved by the U.S. Fish and Wildlife Service or any other agency and it does not necessarily represent the views of all individuals involved in the plan formulation. With modification by the Regional Director of Region 1 of the U.S. Fish and Wildlife Service, it has been prepared under contract by Dr. Patricia P. Douglas and Dr. Robert B. Shaw, Department of Range Science, Colorado State University. It includes recommendations that delineate reasonable actions which are believed to be required to recover Haplostachys haplostachya and Stenogyne angustifolia. This draft recovery plan is subject to modification following review by, and receipt of comments from, cooperative agencies and other informed and interested parties. Goals and objectives will be attained and funds expended contingent upon appropriations, priorities, and other budgetary constraints.

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Acknowledgements

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EXECUTIVE SUMMARY FOR THE RECOVERY PLAN FOR HAPLOSTACHYS
HAPLOSTACHYA AND STENOGYNE ANGUSTIFOLIA.

Current Species Status: Haplostachys haplostachya and Stenogyne angustifolia are restricted to the island of Hawaii, and are federally listed as endangered. All 14 known populations of H. haplostachya (only 2 of which number more than 100 individuals), and 7 of the 9 known populations of S. angustifolia are located at Pohakuloa Training Area (PTA). No estimates of population sizes are available for S. angustifolia.

Habitat Requirements and Limiting Factors: Both species are found in xeric, upper forest zone habitat; the soils originate from Mauna Loa and Mauna Kea lava flows. Historically, both species were collected from a range of elevations and habitat types. Populations at PTA are threatened by military activity; all populations are threatened by alien plant competitors, introduced herbivores, fire, and pathogens.

Recovery Objective: Downlist to threatened status.

Recovery Criteria: The species may be downlisted when 17 populations of H. haplostachya, and 12 populations of S. angustifolia are fenced and naturally reproducing on Hawaii, Maui and Kauai (and/or Molokai for S. angustifolia).

Actions Needed:

1. Secure habitat of current populations and manage threats.
2. Augment extant populations.
3. Establish new populations and manage threats.
4. Conduct research on limiting factors and monitor populations.
5. Validate recovery objectives.

Total Estimated Cost of Recovery (\$1,000):

<u>Year</u>	<u>Need 1</u>	<u>Need 2</u>	<u>Need 3</u>	<u>Need 4</u>	<u>Need 5</u>	<u>Total</u>
1993	13	10	60	158	15	256
1994	114.5	70	60	158	15	417.5
1995	155.5	60	56.5	158	50	480
1996	240.5	62	56.5	172	50	581
1997	121.5	83	86.5	172	50	513
1998	121.5	63	86.5	62	20	353
1999	106.5	30	181.5	62	20	408
2000	106.5	38	196.5	62	20	423
2001	106.5	38	116.5	62	20	343
2002	106.5	32	116.5	62	20	337
2003	106.5	27	116.5	14	20	284
2004	106.5	27	116.5	14	20	284
2005	106.5	27	116.5	14	20	284
2006	106.5	25	106.5	14	20	272
2007	106.5	10	106.5	14	20	257
2008	106.5	10	106.5	14	20	257
2009	106.5	10	106.5	14	20	257
2010	106.5	10	106.5	14	20	257
2011	106.5	10	106.5	14	20	257
2012	106.5	10	106.5	14	20	257
2013	106.5	10	106.5	14	5	242
2014	106.5	10	104	14	5	239.5
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Total	2471	680	2323	1296	490	7259

Date of Recovery: Downlisting to Threatened should initiate in 2014, if recovery criteria are met.

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RECOVERY PLAN FOR HAPLOSTACHYS HAPLOSTACHYA
AND STENOGYNE ANGUSTIFOLIA

I. INTRODUCTION

Brief Overview

Many of the native Hawaiian plants have been negatively impacted since western colonization of the islands. Establishment of agricultural systems, urban development, overgrazing by domestic livestock and feral animals, competition from invading plants, and resultant unnatural fire regimes have drastically altered native ecosystems.

The subjects of this recovery plan, Haplostachys haplostachya and Stenogyne angustifolia (family Lamiaceae, the mint family) are highly endangered in the wild, and all or most of the existing populations of these species are found within the boundaries of the U.S. Army's Pohakuloa Training Area (PTA). Haplostachys and Stenogyne are 2 of 3 genera within the Lamiaceae endemic to the Hawaiian islands.

The genus Haplostachys is comprised of five species, four of which, have gone extinct. The last remaining species is H. haplostachya, a perennial forb originally found on Kauai, Maui, and Hawaii; however, it now occurs exclusively at PTA. Highest densities of H. haplostachya are found on old cinder cones and rocky mounds.

Stenogyne angustifolia is a low-growing, scandent, perennial herb originally found on Kauai, Molokai, Maui, and Hawaii. Of the 20 species within the genus Stenogyne, four are extinct and five are endangered. Stenogyne angustifolia was thought to occur only at PTA, but several recent collections have documented its existence elsewhere on the western side of Hawaii. Stenogyne angustifolia is found occasionally in the same habitats as Haplostachys haplostachya; however, the former has a much wider distribution.

Both Haplostachys haplostachya and Stenogyne angustifolia were presumed extinct until their rediscovery at PTA. Pohakuloa Training

Area supports a substantial portion of the remaining native dry upland forest, shrub and grassland ecosystems on the island of Hawaii. Because of the military presence at PTA, many of these ecosystems have been protected from urban and agricultural development and from overgrazing by domestic livestock. However, alien plant invasion, feral animal disturbance, hunters, and some military activities do present threats to the native vegetation at the installation.

Haplostachys haplostachya and S. angustifolia were federally listed as endangered on October 30, 1979 (Herbst and Faye 1979). The effective date of the listing was November 30, 1979.

Taxonomy

Haplostachys haplostachya and Stenogyne angustifolia are both members of the mint family, Lamiaceae. Within Lamiaceae, the genera Haplostachys, Stenogyne and Phyllostegia are endemic to Hawaii. All three of these endemic genera probably evolved from the genus Gomphostemma (Wagner et al. 1990), a wet-forest genus native to the Indo-Malaysia area.

The name Haplostachys is derived from the Greek words haplo (single) and stachys (spike), referring to the single flower at each axil. The common name of H. haplostachya is "honohono" (Wagner et al. 1990). One meaning of this Hawaiian word is "bad smelling"; however, the flowers are actually fragrant. Three other unrelated taxa also bear the same common name: Dendrobium anosmum, Commelina diffusa, and Oplismenus hirtellus.

Four out of the five species within the genus Haplostachys are considered to be extinct. Haplostachys haplostachya, a perennial herb, is the only surviving member of the genus.

Until very recently, Haplostachys haplostachya was considered to be six separate taxonomic entities. In 1862, Asa Gray described H. haplostachya as Phyllostegia haplostachya based on a collection made between 1838 and 1842, from the sands on a low isthmus on the island of Maui. A second collection, from the mountains on the

island of Kauai was described by Gray as Phyllostegia haplostachya var. leptostachya. In 1888, Hillebrand described Haplostachys grayana based on a collection from the island of Hawaii by Remy. Hillebrand also recognized a variety, H. grayana var. leptostachya based on a collection from the island of Kauai. Sherff described an additional variety, H. grayana var. angustifolia in 1934. St. John (1973) merged all intraspecific taxa except those plants found on the island of Hawaii, which were designated a H. haplostachya var. angustifolia. Since St. John's revisions, all varieties have been eliminated, and consequently, all subdivisions have been merged under the species name Haplostachys haplostachya (A. Gray) St. John (Wagner et al. 1990).

The genus Stenogyne is comprised of 20 species. Stenogyne have been found on the islands of Maui (9 taxa), Hawaii (8 taxa), Molokai (3 taxa), Oahu, Lanai, and Kauai (each with 2 taxa).

Stenogyne is derived from the Greek words stenos (narrow) and gynes (gynaecium), referring to the narrow gynaecium of the genus (Wagner et al., 1990). A common name, "nehenehe", was found by Sherff (1934b) on the label of a specimen of S. angustifolia in Kew Herbarium. However, there are no other references to "nehenehe" as a common name (P. Douglas and R. Shaw, Colorado State University, personal communication 1993). Weller and Sakai (in Wagner et al. 1990) disregarded the common name "nehenehe" for S. angustifolia.

Stenogyne angustifolia was first collected between 1838 and 1842 "in the district of Waimea" on the island of Kauai, and was described by Asa Gray (Kimura and Nagata 1980; St. John 1985). In the mid-1800's. Hillebrand, Wawra, and Remy made subsequent collections of S. angustifolia on the island of Hawaii (Sherff 1934b). Two varieties were described by Hillebrand (1888), one variety from Maui, and the other from Molokai. Hillebrand did not indicate date, collector, nor site description with the varieties. Based predominantly on leaf base morphology, Sherff (1935) recognized the type and five varieties: four from the island of Hawaii, and one each from the islands of Maui and Molokai. Weller and Sakai (1990)

eliminated all subspecific designations. The former varieties are now recognized as synonyms for Stenogyne angustifolia.

Species Description

Haplostachys haplostachya is a perennial herb that grows to a height of 5 feet (1.5 meters). The stems are square and white-woolly (Figure 1). Leaves are simple and narrowly heart-shaped. The upper surfaces of the slightly fleshy leaves are wrinkled and covered with downy, straight, erect hairs. The lower leaf surfaces are densely covered with woolly hairs. Leaf margins are scalloped with shallowly rounded teeth. Showy, stalked flowers are arranged along a terminal main axis. The main axis is 4 to 12 inches (1-3 decimeters) long; two flowers are positioned at each node. The flowers are either pure white, or tinged with purple. The mature fruit is dry, hard, and dark brown; the shape is obconical and three-angled.

Stenogyne angustifolia is an odorless, sprawling perennial herb with trailing stems (Figure 2). Stems are usually hairless (sometimes with a few hairs at nodes) and are square or round. Leaves are simple and hairless, and are 1 to 2 inches (2.5 to 5 centimeters) long, and 0.2 to 0.6 inches (0.5 to 1.5 centimeters) wide, and may be wider and/or pointed at one end (i.e. arrow-head shaped). Teeth on the leaf margin are minute and forward-pointed. Flowers vary in color from dull yellow to magenta; they are externally hairy and occur in pairs at nodes. The fruit are purple-black, nearly spherical, and fleshy; a hardened inner-layer contains the seed.

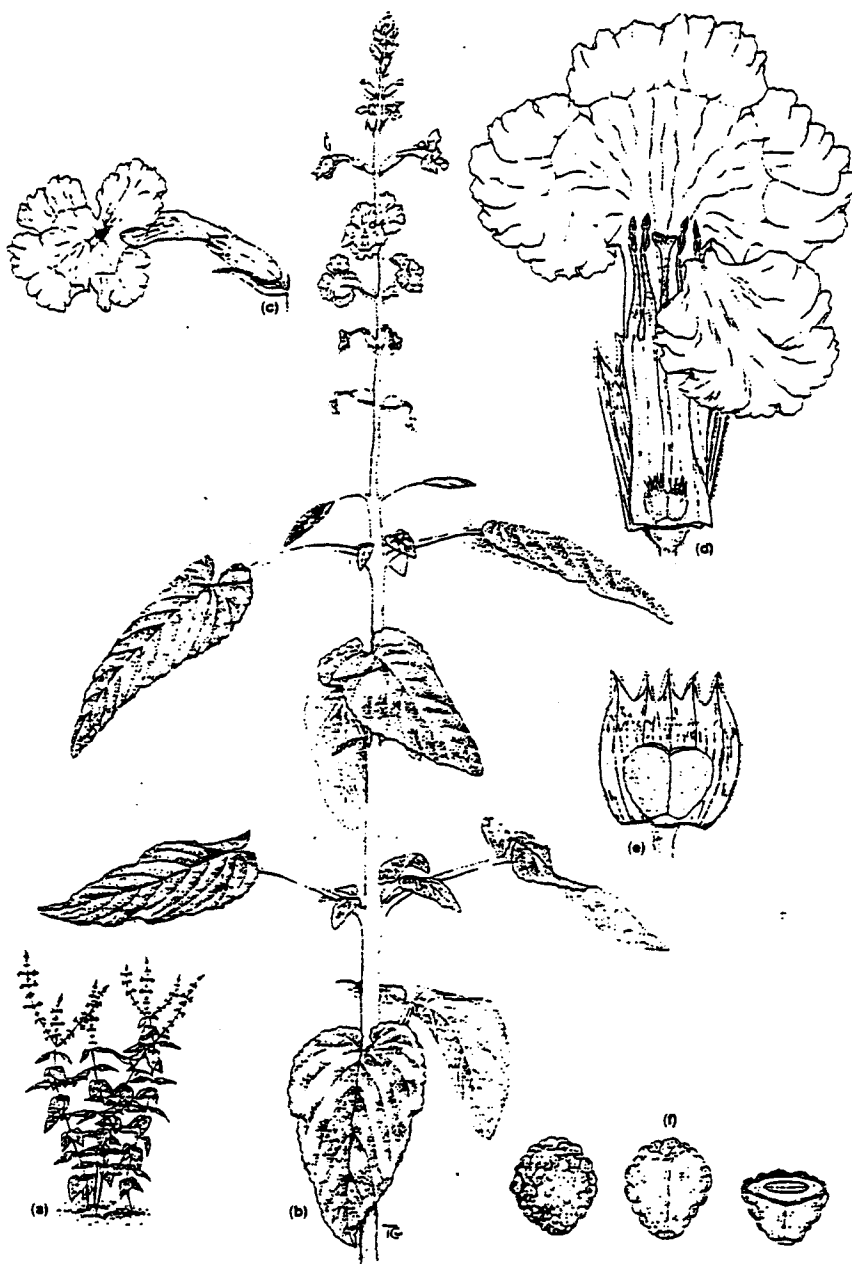


Figure 1. Haplostachys haplostachya: (a) habit, (b) top of stem, (c) flower, (d) expanded corolla, (e) immature fruit, (f) mature fruit)

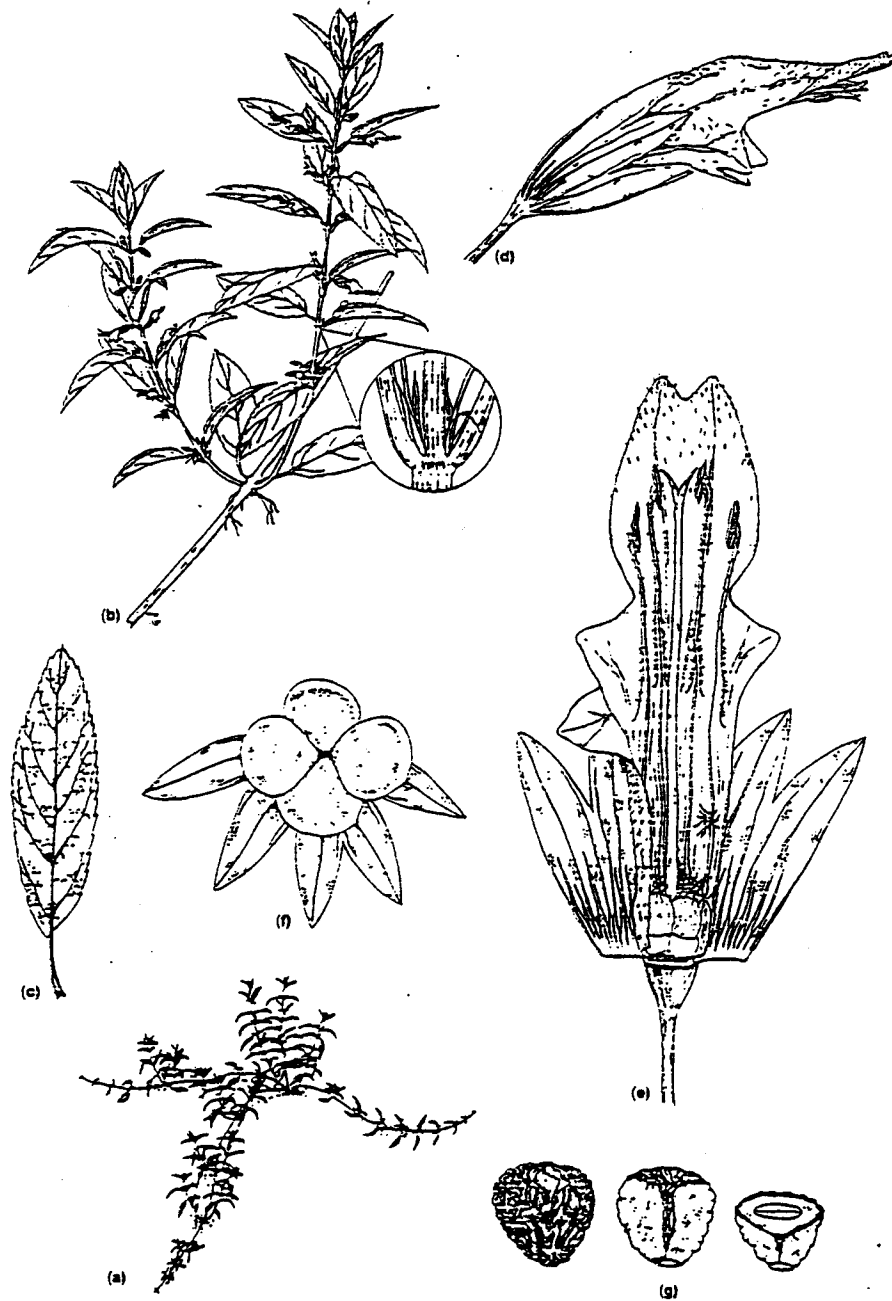


Figure 2. Stenogyne angustifolia: (a) habit, (b) reclining stem, (c) leaf, (d) flower, (e) expanded corolla, (f) immature fruit, (g) mature fruit.

Habitat Description

The general area in which Haplostachys haplostachya and Stenogyne angustifolia are currently found is referred to as Pohakuloa Plateau, a basaltic plain at an elevation of between 5000 and 6000 feet (1500-1800 meters) between the volcanoes Mauna Kea, Mauna Loa, and Hualalai (Figures 3 and 4). The substrate is derived from approximately 20,000 year old lava from Mauna Kea (Lockwood et al. 1988). Highest densities of both species are found on puu (cinder cones) and on tumuli (small hills) at PTA.

The vegetation of this area has been described by several authors. Hillebrand (1888) considered the area as an upper-forest zone, covered by broken lava and stunted vegetation. Ripperton and Hosaka (1942) classified the vegetation as an open forest-scrub zone. Gagne and Cuddihy (1990) described the vegetation as Dodonaea montana shrubland. The scrub component is typical montane, xerophytic vegetation (Table 1).

Semi-Arid Shrubland, Cinder Cones (Puu)

Several populations of Haplostachys haplostachya are situated on cinder cones. The puu are lateral craters 10 to 60 feet (30-200 meters) tall, near the base of Mauna Kea. The puu are rounded as a result of erosion, and are dome-shaped; populations of H. haplostachya occur most frequently on the southern and western slopes of puu. This unusual distribution pattern may be the result of higher moisture availability on these slopes. Fog-drip may supply added moisture to these areas; the puu, particularly the southern and western facing slopes, are the first to intercept the afternoon fog.

Vegetation on puu is comprised mostly of grasses, shrubs, and herbs, with a few scattered trees. The most common native grass is Eragrostis atropioides; however, the alien grass, Pennisetum setaceum occurs in dense stands. A small shrub, Dodonaea viscosa, and Gnaphalium sandwicense var. kilaueanum, an endemic herb, are abundant. Some alien herbs which occupy the puu are Bidens alba, B.

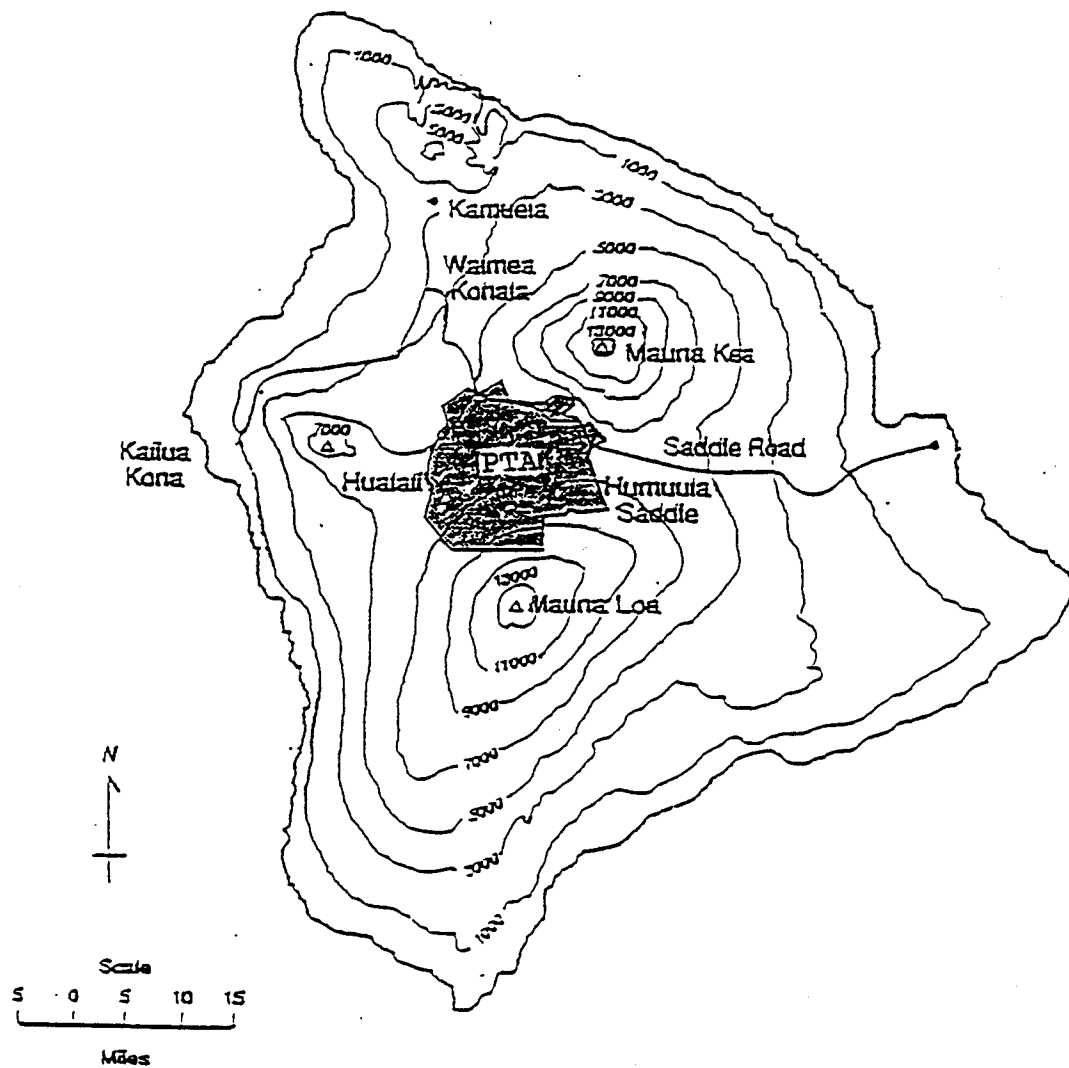


Figure 3. Location of Pohakuloa Training Area on the island of Hawaii, Hawaii.

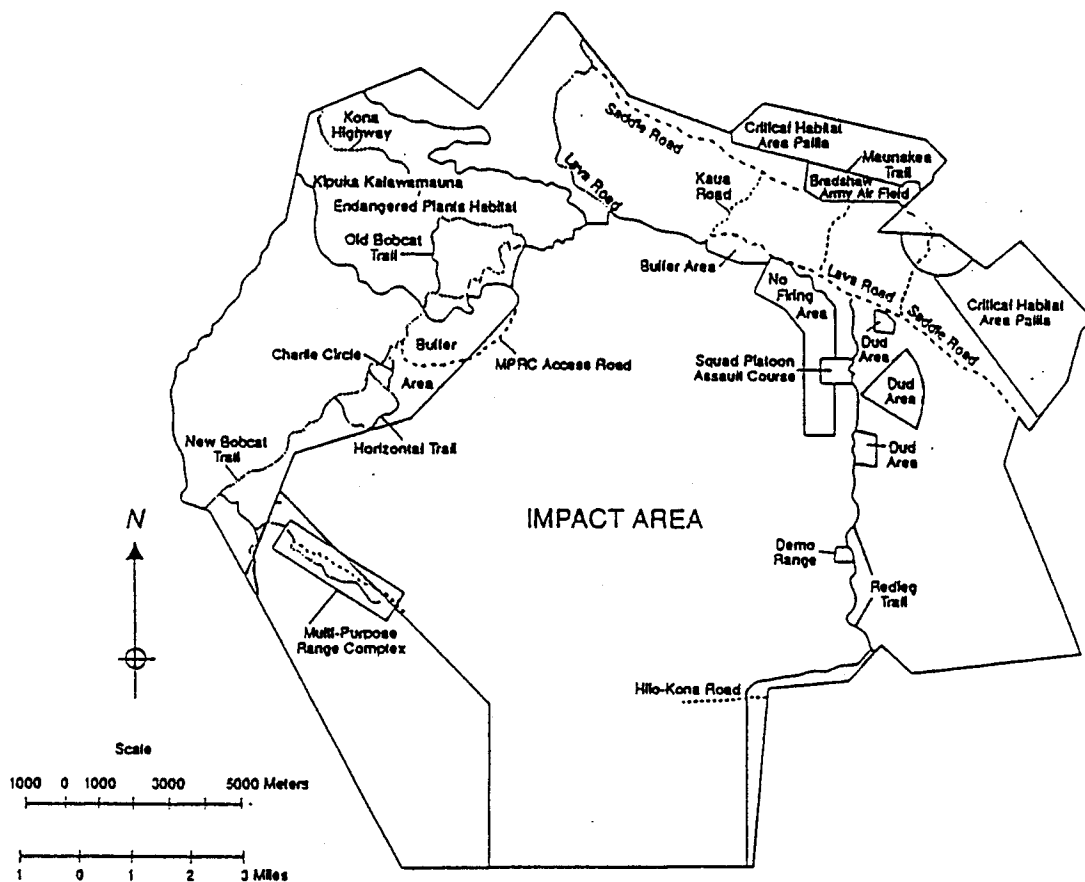


Figure 4. Pohakuloa Training Area on the island of Hawaii, Hawaii.

Table 1. List of plant species associated with the populations of Haplostachys haplostachya and Stenogyne angustifolia at Pohakuloa Plateau.

SCIENTIFIC NAME	NATIVE OR INTRODUCED
<u>Bidens alba</u>	introduced
<u>Bidens pilosa</u>	introduced
<u>Chamaesyce olowaluana</u>	category 2
<u>Chenopodium oahuense</u>	
<u>Crassula sieberiana</u>	introduced
<u>Dondonaea viscosa</u>	indigenous
<u>Dubautia linearis</u>	
<u>Eragrostis atropioides</u>	
<u>Erodium cicutarium</u>	introduced
<u>Gnaphalium sandwicense</u>	endemic
<u>Helichrysum foetidum</u>	introduced
<u>Hesperocnide sandwicensis</u>	category 1
<u>Heterotheca grandiflora</u>	
<u>Lipochaeta</u> sp.	endemic
<u>Marrubium vulgare</u>	introduced
<u>Metrosideros polymorpha</u>	
<u>Myoporum sandwicense</u>	
<u>Opuntia ficus-indica</u>	introduced
<u>Osteomeles anthyllidifolia</u>	
<u>Pennisetum setaceum</u>	introduced
<u>Senecio sylvaticus</u>	introduced
<u>Sida fallax</u>	
<u>Sigesbeckia orientalis</u>	
<u>Silene lanceolata</u>	endangered
<u>Sophora chrysophylla</u>	
<u>Stenogyne microphylla</u>	endemic
<u>Styphelia tameiameia</u>	
<u>Tagetes minuata</u>	introduced
<u>Tetramolopium arenarium</u>	category 1
<u>Tetramolopium consanguineum</u>	candidate, category 2
<u>Vaccinium reticulatum</u>	
<u>Verbena litoralis</u>	introduced
<u>Vicia sativa</u>	introduced
<u>Zanthoxylum hawaiiense</u>	category 2

Key to terms used in table 1.

endemic	=	native only to Hawaii
indigenous	=	native to Hawaii, but found elsewhere
endangered	=	listed as an endangered species
category 1	=	substantial information exists; listing the taxa as endangered or threatened may be warranted.
category 2	=	some information exists; listing the taxa as endangered or threatened may be warranted, but more data is needed.
introduced	=	not native to Hawaii
introduced, polynesian	=	not native to Hawaii, but introduced before European contact

pilosa, Erodium cicutarium, Helichrysum foetidum, Marrubium vulgare, Senecio sylvaticus, Tagetes minuata, Verbena litoralis, and Vicia sativa ssp. nigra. The trees, Myoporum sandwicense and Sophora chrysophylla, are infrequent and are mainly confined to deeply eroded gullies on the puu's.

Metrosideros Woodland, Rock Outcrops

Only one individual of Stenogyne angustifolia was found on a tumulus in association with a Metrosideros polymorpha woodland. The plant occurs on a young Mauna Loa lava flow (3,000 years old). Tetramolopium consanguineum, a Category 2 candidate, is prolific throughout the area. Several individuals of Stenogyne microphylla also are found in the area. One individual of Zanthoxylum hawaiiense, a Category 2 tree, is located in close proximity. The native shrubs, Dodonaea viscosa, Styphelia tameiameia, and Vaccinium reticulatum Sm., are abundant. Grasses and herbs occur infrequently; stands of Eragrostis atropioides and Pennisetum setaceum are found occasionally. Heterotheca grandiflora, Sigesbeckia orientalis, and Senecio sylvaticus are present, but uncommon.

Semi-arid Shrubland, Rock Outcrops (Tumuli)

Six of the seven populations of Stenogyne angustifolia, and several populations of Haplostachys haplostachya are found in semi-arid shrubland. The topography includes large rock outcrops, 10 to 330 feet (3 to 100 meters) across, and 3 to 65 feet (1 to 20 meters) high, protruding through the layers of ash.

The plant species that occur in association with Haplostachys haplostachya and S. angustifolia in this habitat type, include: Dodonaea viscosa, which is the dominant shrub on all tumuli sites. Dubautia linearis, Osteomeles anthyllidifolia, Sida fallax, and Styphelia tameiameia are also common. Gnaphalium sandwicense var. kilaueanum is the dominant native herb. Myoporum sandwicense and Sophora chrysophylla occur in areas where soil accumulates. Eragrostis atropioides is the dominant native grass; however, dense stands of the introduced grass, Pennisetum setaceum are widespread.

The following alien taxa are common: Helichrysum foetidum, Heterotheca grandiflora, Senecio sylvaticus, Tagetes minuata, and Vicia sativa ssp. nigra.

Several Haplostachys haplostachya populations occur with other endangered, threatened, or infrequent taxa. These sites of special interest are the following:

Site 11. The only extant population of Tetramolopium arenarium (a Category 1 taxon) grows here. Also, Stenogyne angustifolia grows prolifically among H. haplostachya and T. arenarium.

Site 12. In this area, Chamaesyce olowaluana (a Category 2 taxon) is a dominant native tree. One small specimen of Stenogyne angustifolia was located in a lava rock crevice.

Site 14. This population consists of several thousand individuals. A small population of Silene lanceolata (federally listed as endangered) persists in this area on rocky tumuli. Chenopodium oahuense, a native shrub, is relatively frequent, as well as an unidentified Lipochaeta taxon. Several individuals of Opuntia ficus-indica occur on an adjacent rocky outcrop.

Several Stenogyne angustifolia populations occur with other endangered, threatened, or infrequent species. These sites of special interest are as follows:

Site 1. Two individuals of Stenogyne angustifolia have been found in a grassland composed mostly of Eragrostis atropioides and Pennisetum setaceum. Individuals of Chenopodium oahuense are scattered throughout the area. S. angustifolia may be infrequent as a result of repeated burning and competition from alien species. This area may have supported a Chenopodium shrubland in the past.

Site 5. Stenogyne angustifolia grows abundantly with Haplostachys haplostachya on rocky outcrops. Stenogyne angustifolia also coexists with Tetramolopium arenarium in areas where the lava is degraded and soil accumulation is

fairly deep. Chamaesyce olowaluana is scattered along the rocky ridges in the immediate area.

Site 7. Several individuals of Stenogyne angustifolia grow in a Dodonaea/Styphelia and Myoporum/Sophora scrubland. The substrate is derived from Mauna Loa volcanics and is comprised of degraded, discontinuous pahoehoe (smooth lava) overlain by ash deposits of varying depths. These individuals need careful study, since most of them appear to have intermediate characters. Specimens were confirmed to be possible hybrids or backcrosses between S. angustifolia and S. rugosa. Although no pure stands of S. rugosa are found at PTA, hybridization may have occurred at an earlier time. (Dr. Steven G. Weller, Department of Ecology and Evolutionary Biology, University of California at Irvine, personal communication 1992). Hybridization between S. microphylla and S. rugosa also may have occurred at PTA. Hesperocnide sandwicensis, a category 1 taxon, grows in an adjacent area. A small, recently introduced annual, Crassula sieberiana, is locally abundant and occurs only at PTA.

Historic Range and Population Status

Historically, Haplostachys haplostachya occurred on three Hawaiian Islands: Kauai, Maui, and Hawaii. The taxon was once known from, but is now presumed extirpated in the following areas: (1) the mountains on the island of Kauai, (2) the sands of a low isthmus, and at Kaula on the island of Maui; and (3) the slopes of Mauna Kea near Waikii and the slopes of crater Nohonaohae in the plains of Waimea, on the island of Hawaii.

Historically, the geographic range of Stenogyne angustifolia included four islands: Hawaii, Maui, Kauai and Molokai. Hillebrand (1888) described the taxon as "not common". Throughout the Hawaiian Islands, populations of S. angustifolia declined for more than 100 years until, in 1949, it was presumed extinct.

Present Distribution

Maps or descriptions of the exact locations of known individuals will not be included in this Plan due to the possibility that vandalization or unauthorized collection could be encouraged by the public release of this information. The U.S. Fish and Wildlife Service will maintain this information in its files, where it is available to the public through the procedures of the Freedom of Information Act.

Since the discovery of the first population of Haplostachys haplostachya in 1977, 13 additional populations have been located. This increase may reflect true expansion, or sampling bias towards flowering individuals. All 14 populations of H. haplostachya are located in a 5000 acre (2000 hectare) area of PTA. Only two populations number more than 100 individuals; however, all the known populations appear to be healthy, and may be expanding (Douglas and Shaw, personal communication 1993).

In 1977, a small population of Stenogyne angustifolia (fewer than 10 individuals) was discovered by L. Stemmerman within the EPH (Endangered Plant Habitat) at PTA (Kimura and Nagata, 1980). Currently, at least seven populations are known to occur at PTA. Collections from two sites outside PTA (Puu Anahulu and Waikoloa) have also been made; however, little information is available on these populations. There are no recent collections of S. angustifolia from any other Hawaiian island.

Stenogyne angustifolia is scattered to locally abundant on rocky ridges in portions of EPH, and frequently occurs with Haplostachys haplostachya. The populations are healthy and appear to be expanding from the distribution reported by Herbst and Fay (1979).

Life History - Haplostachys haplostachya

Information on the life history of Haplostachys haplostachya is limited (Wagner et al. 1990). Because individuals probably die back to the roots during the dry season, and dead material may persist for

several years (Derral R. Herbst, Botanist, U.S. Army Corps of Engineers, personal communication 1992), reliable estimates of the populations' ages cannot be made without further research. No information on the turnover rates of plants and/or stems, seedling recruitment rates, seedling survival rates, etc., is available.

The pollination vectors for Haplostachys haplostachya have not been documented; however, the pale flowers, long corolla tube and convoluted aperture of H. haplostachya are characteristic of moth pollinated species. Moths have been observed in the area, particularly in the evening. Nectar may be secreted from a swollen gland at the base of the ovary; however, no data about nectar quantity or sucrose concentration is available.

The suite of pollinators may change throughout a twenty-four-hour period, enhancing successful pollination; a variety of insect species have been observed on and around the flowers. The specific mechanisms of pollination are unknown, but fruit set is between 70 and 95%, and seed crops ranged from 30-536 seeds per square yard (square meter), with 51-655 seeds per plant (Aplet et al. 1991a). It is not known if the species is self-compatible or requires cross fertilization.

Dispersal mechanisms, viability, longevity, and dormancy requirements of Haplostachys haplostachya seeds are also unknown. The woody nutlet coat suggests that the fruit persists intact for a long period. Aplet et al. (1991a) planted 500 seeds, half scarified and half unscarified. Of these, only three of the scarified seeds and no unscarified seeds germinated.

Life History - Stenogyne angustifolia

Information concerning the population biology of this species is limited to studies conducted by Aplet et al. (1991b). Shoots of Stenogyne angustifolia begin to recline and trail on the ground as they mature, and flowers are borne exclusively on these decumbent shoot systems. The density of plants on study plots established by Aplet et al. (1991b) ranged from 9.2 to 28.3 stems per square yard

(square meter). Annual seed production ranged from zero to 16 fruit-bearing calyces per square yard (square meter).

Vegetative cloning is an important means of reproduction. Shoots root at leaf nodes, ultimately forming independent plants. Plants also spread by a network of rhizomes. Because Stenogyne angustifolia propagates by rhizomes, stolons, and aerial shoots, it is difficult to define individual plants (genets-genetic individuals) from shoots of an individual (ramets). Consequently, it is difficult to estimate true population sizes.

Exact means of sexual reproduction are unknown for Stenogyne angustifolia. Plants have been observed flowering during most months of the year (except in October and November of 1989, after an unusually dry period). Flowers are bisexual; however, it is unknown if individuals are capable of self-fertilization.

Although most species of mints have dry nutlets, Stenogyne has fleshy fruit which may facilitate dispersal (Carlquist 1980). Carlquist (1980) indicated that bird dispersal of seeds is common on the islands, and other mint taxa appear to be dispersed by birds on the plateau. Seed dispersal may be affected positively by both native and introduced birds.

The degree of pollinator specificity, as well as other factors of pollination biology, are currently unknown and require research. The lack of odor, flower shape and color, stamen position, and quantity of nectar suggest that Stenogyne angustifolia is probably pollinated by native Honeycreeper birds (Weller and Sakai, 1990). Moreover, numerous insects have been observed crawling upon the stems, leaves, and flowers, and may also serve as pollination vectors.

Little is known about seed viability, longevity, and dormancy requirements, but Aplet (Forest Ecologist, The Wilderness Society, Washington, D.C., personal communication 1991) has recently found that seed coat removal increases germination rates.

Reasons for Decline and Current Threats

The exact cause(s) of the decline of Haplostachys haplostachya and Stenogyne angustifolia are unknown; however, our ability to conserve rare and endangered species is dependent upon developing an understanding of factors that lead to rarity (Fritz-Sheridan 1988). The flora of the Hawaiian Islands are particularly vulnerable to environmental stress, and have been heavily impacted by human caused disturbances. For example, conversion of land for agriculture, housing, and military uses have undoubtedly contributed to the species' decline. In addition, much of PTA is undergoing primary succession (Aplet et al. 1991a) and is susceptible to fire and invasion by exotic organisms (Herbst and Fay 1979; Douglas et al. 1989). Loss of native pollinators, and hybridization may also contribute to the decline of native plant species.

1. Land Conversion. Historically, ancient Hawaiians cleared land for subsistence farming. For example, Sophora chrysophylla, a native tree, was harvested as late as the 1950s for fence posts. To date, the sugarcane, pineapple, and coffee industries have removed much of the native vegetation, particularly in the lowlands. The destruction of available habitat by clearing for urbanization and industrialization may also have contributed profoundly to the demise of the taxa, although these activities are not known to be threats to the existing sites.

2. Military Use. Construction of military facilities, including the building of new roads and maintenance of old roads, may affect populations of Haplostachys haplostachya and Stenogyne angustifolia at PTA by intruding into habitat space.

3. Trampling. Trampling, as well as dust raised by passing vehicular traffic generated by activities related to public hunting and military maneuvers, may pose a threat to both taxa. Trampling by

feral animals, especially pigs (which root as well) and goats, is also a source of concern.

4. Herbivory. The first domestic animals to become established in the islands of Hawaii were pigs introduced by Polynesians in the fourth or fifth century A.D. Goats were introduced by Captain Cook in 1778, sheep by Colnett in 1791 and Vancouver in 1793 (Herbst, personal communication 1992). Feral pigs, goats and sheep are commonly found at PTA.

Excessive grazing and browsing by feral animals may alter and limit the natural habitat sufficiently to preclude the survival of Haplostachys haplostachya and Stenogyne angustifolia. Feral animals have been observed browsing inflorescences of H. haplostachya (Aplet *et al.* 1991a; 1991b).

5. Competition. Numerous adventive species, particularly the alien grass, Pennisetum setaceum, compete with Haplostachys haplostachya and Stenogyne angustifolia. H. haplostachya and S. angustifolia originally occurred throughout the semi-arid shrublands, but presently they persist only on cinder cones and rock outcrops, where the competition from alien species is probably reduced.

6. Loss of Pollinators and Seed Dispersers. If the pollination and seed dispersal mechanisms are zoophilous, animal vectors are obviously necessary.

a. Loss of Pollinators. Reduction of habitat (Aplet *et al.* 1991a; 1991b), introduction of competitors, diseases, and other factors that impact native nectivorous bird species may have led to the reduction of available pollinators, thus severely limiting reproductive capabilities and viability of the species. In addition, the introduction of insectivorous birds and insects that feed on, or compete with native insect

species, and the use of pesticides and fertilizers, may detrimentally influence the number and types of native insect pollinator species, thus affecting the viability of the taxa.

b. Loss of Seed dispersers. Seed dispersion may also have been negatively impacted by the reduction of native animal vectors; however, it is possible that introduced species also contribute to seed dispersal.

7. Catastrophic Events. It is possible, given the limited range of the species, that a single catastrophic event could extirpate all, or a great majority of the remaining wild individuals of these species.

a. Fire. Fire in arid regions is always consequential. PTA has frequent fires, primarily the result of military maneuvers, and occasionally as a result of lightning, or volcanic eruptions. Fire at PTA can be sustained by the vegetation at any time of the year, even after a rain (Vogl 1969).

b. Other Stochastic Disasters. Most of the remaining populations of both species occur in xeric areas, largely unprotected from high winds, and prone to erosion. This severe environment multiplies the impacts of natural disasters, such as hurricanes and earthquakes.

8. Hybridization. Hybridization may affect the integrity of a taxon. Weller and Sakai (1990) indicated that hybridization does occur at PTA, possibly between several different species of Stenogyne. Stenogyne microphylla is fairly abundant at the installation, and hybrids, believed to be crosses between S. angustifolia and S. rugosa (Dr. Steven G. Weller, personal communication 1992) are present at PTA. Stenogyne rugosa has not been located at PTA, but may have occurred there historically.

Hybridization is not as great a concern for Haplostachys haplostachya, since it is the only surviving species in the genus. Hybridization between Phyllostegia and Haplostachys is plausible but unlikely, because Phyllostegia has not been documented to occur at PTA, where populations of H. haplostachya are located.

Conservation Efforts

1. Federal Actions.

(a) Legal Protection. Haplostachys haplostachya and Stenogyne angustifolia were federally listed as endangered on October 30, 1979 (Herbst and Faye 1979). The decision was based principally on status reports by Derral Herbst (1977; 1978). Listing did not include critical habitat.

(b) Protection from military activity. After the rediscovery of H. haplostachya and S. angustifolia in 1977, the EPH was designated by the Army as a protected area. Several rare plant taxa, including H. haplostachya, S. angustifolia, and what was thought at the time to be Lipochaeta venosa (to date, L. venosa has not yet been positively verified) have been found within the EPH. Within the EPH, all military activities are restricted to roads and to fixed artillery firing points.

2. State of Hawaii actions.

(a) Legal protection. The State of Hawaii listed Haplostachys haplostachya and Stenogyne angustifolia as endangered species in 1979 following the federal listing, pursuant to Chapter 195D of the Hawaii Revised Statutes.

(b) Protection from military activity. Populations outside the EPH were unprotected from military activities until, in 1991, an agreement was made between the Army and the State Department of Land and Natural Resources (DLNR) which resulted in the placement of a four-foot fence around Puu Ka Pele to protect a newly discovered population of H. haplostachya. A

road was widened around the Puu to facilitate the building of the fence.

3. Research activities.

In 1989, four permanent field monitoring plots were established for Haplostachys haplostachya and five for Stenogyne angustifolia in order to provide information on the life histories of these species (R. Shaw and P. Douglas, personal communication 1992).

(a) Population data. The available data for H. haplostachya is summarized in Table 2; the data for S. angustifolia is summarized as follows: The density of S. angustifolia ranged from 9.2 to 28.3 stems per meter²(yard²); the mean was 17.8 stems per meter² (yard²) ± 7.5 on study plots. Annual seed production ranged from 0-16 fruit-bearing calyces per meter² (yard)², with a mean of 3.3.

(b) Cultivation. It was found that removing the seed coat increases germination rates in S. angustifolia. Scarification appears to improve germination in H. haplostachya, but germination rates are still very low. Only 3 scarified seeds out of 250 germinated, while 0 out of 250 unmanipulated seeds germinated (Aplet et al. 1991a).

Table 2. Demographic data for four populations of Haplostachys haplostachya at Pohakuloa Training Area, Hawaii (Aplet et al. 1991a).

Site #	Area (hectare)	Number of Plants	Density in 100 m ² plot	Evidence of Reproduction
3	≈ 5-10	≈ 10,000	SW plot = 190 NE plot = 40	14% of plants in NE plot w/ no dead shoots, may indicate young plants
9	≈ 2	≈ 100	36.8 in plot. Decreases away from plot	Very few plants appear to be young, no seedlings
10	< 0.25	≈ 100	42.9	Several plants of recent origin, several plants retained dead shoots
12	< 0.01	41	≈ 40	33% of plants had > 50 dead shoots, 1 appeared to be a seedling

II. RECOVERY

Objectives

This recovery plan establishes the framework within which efforts are undertaken to ensure the long-term survival of Haplostachys haplostachya and Stenogyne angustifolia under natural conditions. Target objectives are provided first for increasing and stabilizing population sizes and numbers, followed by downlisting to threatened status, and finally delisting, with the complete removal of all federal protective status.

Downlisting to Threatened Status

Haplostachys haplostachya and Stenogyne angustifolia can be considered for downlisting to threatened status once:

1. Existing habitat on the island of Hawaii is secured and managed to perpetuate the species at those locations.
2. Three additional populations of each species are reestablished in secure, managed habitat on Maui and Kauai (and/or Molokai for S. angustifolia) to preclude the possibility of the species being irreversibly devastated by some stochastic event.

Delisting

Consideration for delisting can occur once:

1. The downlisting targets are realized.
2. Threats are reduced or eliminated to allow the 17 populations of Haplostachys haplostachya, and 12 populations of Stenogyne angustifolia to reproduce unassisted.
3. Populations must be stable or increasing. In addition, these populations should be comprised of an adequate number of reproductive, self-regenerating adults to produce a mixture of reproductive stages (e.g. seedlings, juveniles, and adults) adequate to ensure the self-perpetuation of the populations.

STEP-DOWN OUTLINE

1. Secure and stabilize the known populations of Haplostachys haplostachya and Stenogyne angustifolia.
 11. Secure and manage the populations at Pohakuloa.
 111. Enter into long-term agreements to secure and manage the EPH at Pohakuloa.
 112. Enter into long-term agreements to secure and manage the populations outside of the EPH at Pohakuloa.
 12. Secure and manage the Waikoloa population of Stenogyne angustifolia.
 121. Conduct a thorough survey of Waikoloa.
 122. Enter into long-term agreements to secure and manage the populations at Waikoloa.
 13. Secure and manage the Puu Anahulu population of Stenogyne angustifolia.
 131. Conduct a thorough survey of Puu Anahulu.
 132. Enter into long-term agreements to secure and manage the populations at Puu Anahulu.
 14. Construct fenced exclosures around all extant populations.
 141. Construct fence around the EPH.
 142. Complete construction of fences around extant populations outside of the EPH at Pohakuloa.
 143. Construct a fence around the Waikoloa population.
 144. Construct a fence around the Puu Anahulu population.
 15. Control threats to the Pohakuloa populations.
 151. Maintain fenced exclosures at Pohakuloa.
 152. Control fire.
 1521. Develop methods of controlling fire.
 1522. Implement fire control plans.
 153. Control alien plants.
 154. Control introduced birds.
 155. Control insect predators.
 156. Control diseases.
 157. Control military activities.

2. Determine factors limiting growth and reproduction.
 21. Determine the effects of introduced plants.
 22. Determine the effects of introduced birds on reproduction.
 23. Determine the effects of introduced insects.
 24. Determine the effects of diseases.
 25. Determine the effects of military activities.
3. Develop methods of controlling the factors that limit growth and reproduction.
 31. Develop methods to control introduced plants.
 32. Develop methods to control introduced birds.
 33. Develop methods to control introduced insects.
 34. Develop methods to control diseases.
 35. Develop methods to limit the impacts of military activities.
4. Control feral animal populations.
 41. Assess the level of feral animal damage at Waikoloa.
 42. Assess the level of feral animal damage at Puu Anahulu.
 43. Allow unlimited hunting.
 44. Develop and implement methods of feral pig control.
5. Conduct surveys to locate all undiscovered populations.
 51. Conduct surveys to locate populations of H. haplostachya.
 52. Conduct surveys to locate populations of S. angustifolia.
6. Secure and stabilize newly discovered populations of H. haplostachya and S. angustifolia.
 61. Enter into long-term agreements with land owners to secure and manage any newly discovered populations.
 62. Construct fenced exclosures.
 63. Control threats to any newly discovered populations.
 631. Maintain fenced exclosures.
 632. Control alien plants.
 633. Control introduced birds.
 634. Control insect predators.
 635. Control diseases.
7. Develop and implement plans to augment the extant population, and create new populations.

- 71. Conduct basic research on the genetic variability of extant plants.
- 72. Develop appropriate propagation techniques.
 - 721. Establish propagule banks.
 - 722. Develop standards for optimum production of propagules.
 - 723. Determine impacts of harvesting propagules.
 - 724. Develop criteria for storage of propagules.
- 73. Select genetic stock to use in augmenting existing populations and establishing new populations.
- 74. Determine appropriate introduction techniques.
 - 741. Determine optimal habitat requirements for growth and reproduction.
 - 742. Select specific areas for augmentation.
- 75. Augment existing populations with transplanted individuals.
- 76. Locate potential habitat areas for additional populations.
 - 761. Conduct surveys of Maui, Kauai, and Molokai.
 - 762. Secure the potential habitat sites.
 - 7621. Enter into long-term agreements with land owners to secure and manage any newly established populations.
- 77. Construct fenced exclosures.
- 78. Determine appropriate introduction strategy.
 - 781. Conduct surveys to identify specific sites for introduction.
 - 782. Transplant propagules into new habitat areas.
- 79. Control threats to the newly established populations.
 - 791. Maintain fences.
 - 792. Control alien plants.
 - 793. Control alien birds.
 - 794. Control insect predators.
 - 795. Control diseases.
- 8. Develop and maintain a detailed monitoring program.
 - 81. Map, tag, and monitor all wild plants.

82. Map, tag, and monitor all transplanted plants.
9. Verify or determine the scientific validity of the recovery objectives.
 91. Determine the number of populations needed to ensure survival over the next 200 years.
 92. Determine the number of individuals needed to ensure the long-term survival of each population.
 93. Determine the breeding system and susceptibility to inbreeding depression.
 94. Determine whether the hypothesized human-induced changes in climate will affect the populations.

NARRATIVE

1. Secure and stabilize the known populations of Haplostachys haplostachya and Stenogyne angustifolia.

The last remaining wild populations must be preserved, and the surrounding habitat protected, in order for the populations to expand, either by natural or artificial means. In order to accomplish this task, it will be necessary to secure landowner cooperation at each site. Agreements with the landowner should be long-term and precisely detail what actions are anticipated.

In addition, the remaining wild plants must be protected from direct threats to their survival. To accomplish this objective, the biological requirements for successful reproduction must be understood, and all introduced predators and competitors of H. haplostachys and S. angustifolia must be evaluated and brought under control.

11. Secure and manage the populations at Pohakuloa.

All the known extant populations of Haplostachys haplostachya and 7 out of 9 extant populations of Stenogyne angustifolia are located at PTA. Because of the importance of this area as habitat for native plant species, it is imperative that arrangements are made to ensure the continued existence of the species.

111. Enter into long-term agreements to secure and manage the EPH at Pohakuloa.

The 10 populations of Haplostachys haplostachya and four populations of Stenogyne angustifolia located within the

EPH are currently managed by the military. Steps should be taken to ensure that the 14 populations are secured via a long-term agreement between the U.S. Fish and Wildlife Service (Service), DOFAW, and the Department of the Army (DOA).

112. Enter into long-term agreements to secure and manage the populations outside of the EPH at Pohakuloa.

Four populations of Haplostachys haplostachya and three populations of Stenogyne angustifolia are located within the Army's Pohakuloa Training Facility, but outside of the EPH. Some level of protection from threats must be procured for these populations in terms of long-term agreements between the Service, DOFAW, and the DOA.

12. Secure and manage the Waikoloa population of Stenogyne angustifolia.

Because little information is available on the status of these populations, a thorough survey should be conducted to find the exact locations of these populations. Once located, steps should be taken to ensure these populations are protected from threats.

121. Conduct a thorough survey of Waikoloa.

The last collection of S. angustifolia from the Waikoloa area was in 1985. All extant plants should be located, and threats should be assessed (see Task #2).

122. Enter into long-term agreements to secure and manage the populations at Waikoloa.

Steps should be taken to ensure that all extant populations in the area are secured via long-term agreements between the landowners, DOFAW, and the Service.

13. Secure and manage the Puu Anahulu population of Stenogyne angustifolia.

See narrative for task #12.

131. Conduct a thorough survey of Puu Anahulu.

The last collection of S. angustifolia from Puu Anahulu was in 1978. All extant plants should be located, and all threats to their survival should be assessed (see Task #2).

132. Enter into long-term agreements to secure and manage the populations at Puu Anahulu.

See narrative for Task #122.

14. Construct fenced exclosures around all extant populations.

It is important that fencing of the existing populations be completed as soon as possible. Fencing is essential, in order to protect the populations from grazing and rooting by feral animals, and trampling by foot or vehicles, or cutting for camouflage by military units at Pohakuloa.

141. Construct fence around the EPH.

While it is desirable to fence as large an area as possible, it is more important that fencing be completed as quickly as possible in order to provide short-term protection of populations, although it will not adequately ensure the survival of the species.

142. Complete construction of fences around extant populations outside of the EPH at Pohakuloa.

A fence was built around Puu Ka Pele to protect a population of Haplostachys haplostachya in 1991. However, 3 additional populations of H. haplostachya and 3 populations of A. angustifolia remain without any protection from feral animals, or trampling as a result of military disturbance and hunters.

143. Construct a fence around the Waikoloa population.

See narrative for Task #141.

144. Construct a fence around the Puu Anahulu population.

See narrative for Task #141.

15. Control threats to the Pohakuloa populations.

All known threats to the existence of the Pohakuloa populations of haplostachys haplostachya and Stenogyne angustifolia both within and outside of the EPH must be controlled or removed.

151. Maintain fenced exclosures at Pohakuloa.

The exclosure sites will need to be visited on a regular basis and the fences examined and repaired several times per year to ensure maximum protection from feral animals and trampling by people and vehicles.

152. Control fire.

Fire is a constant threat to populations at Pohakuloa because of the military activity and the xeric nature of the environment.

1521. Develop methods of controlling fire.

Methods of controlling, or minimizing fires must be developed. Techniques might, for instance, include the construction of fire-breaks.

1522. Implement fire control plans.

Once the effects and methods of controlling fires are determined, steps should be taken to minimize the likelihood of fires in habitat areas.

153. Control alien plants.

Once the effects (Task #21), and methods of controlling (Task #31) noxious weeds are determined, steps should be taken to control these alien plants within the exclosures.

154. Control introduced birds.

Based on the results of Task #22 and Task #32, methods of controlling introduced birds that hinder reproductive processes of Haplostachys haplostachya and Stenogyne angustifolia should be implemented.

155. Control insect predators.

Predation by insects must be controlled within the exclosures. Based on the results of Task #23 and Task #33, monitoring and control programs should be initiated which will detect these problems at the earliest possible time.

156. Control diseases.

Diseases must be controlled within the exclosures. Monitoring programs should include means of immediate detection and treatment of diseases affecting the growth and survival of Haplostachys haplostachya and Stenogyne angustifolia. Protocols should be established according to the results of Task #24, and Task #34.

157. Control Military Activities.

Military activities should be minimized within the exclosures. Based on the results of Task #25 and Task

#35, monitoring programs should be established to detect any problems as a result of these activities in surrounding areas.

16. Control threats to the Waikoloa population.

All known threats to the existence of the Waikoloa populations of Stenogyne angustifolia must be controlled or removed.

161. Control alien plants.

See narrative for Task #153.

162. Control introduced birds.

See narrative for Task #154.

163. Control insect predators.

See narrative for Task #155.

164. Control diseases.

See narrative for Task #156.

17. Control threats to the Puu Anahulu population.

All known threats to the existence of the Puu Anahulu populations of S. angustifolia must be controlled or removed.

171. Control alien plants.

See narrative for Task #153.

172. Control introduced birds.

See narrative for Task #154.

173. Control insect predators.

See narrative for Task #155.

174. Control diseases.

See narrative for Task #156.

2. Determine factors limiting growth and reproduction.

In order to develop an adequate management and control program, it is necessary to determine all of the factors that are limiting the growth and reproduction of the species. It is particularly important to determine the relative impact of each hypothesized threat on the

survival and reproduction of Haplostacys haplostachya and Stenogyne angustifolia.

21. Determine the effects of introduced plants.

Determination of the mechanisms by which alien plants impact H. haplostachya and S. angustifolia will better enable the manager to combat the alien plant problem and control the spread of such plants into areas where H. haplostachya, S. angustifolia and other native plants are located.

22. Determine the effects of introduced birds on reproduction.

The effects of introduced birds on reproduction of H. haplostachya and S. angustifolia need to be addressed. The specific mechanism by which they impact the species, such as elimination of the natural pollinators by competition with native birds or predation of native insects need to be determined.

23. Determine the effects of introduced insects.

Knowledge of the effects of insect predation on native plants, or competition with native pollinator species, and the mechanisms by which they affect the survival and reproduction of H. haplostachya and S. angustifolia is integral to the recovery of the species.

24. Determine the effects of diseases.

In order to efficiently manage populations of H. haplostachya and A. angustifolia, it will be necessary to assess the severity of all threats to the populations. Understanding the mechanisms and the effects of diseases on the plants is an essential component of a successful management plan.

25. Determine the effects of military activities.

PTA is the largest military training facility in Hawaii; more than 50% of the installation's land area is designated as ordinance impact zone. In addition to ordinance impact areas, dud areas, a demolition range, and a platoon assault course are potential sources of disturbance that may limit reproduction and growth in resident native plants, including H. haplostachya and S. angustifolia. A thorough assessment of the threats to the populations, as a result of military operations at PTA needs to be made, and the populations should be closely monitored for signs of possible negative effects.

3. Develop methods of controlling the factors that limit growth and reproduction.

Methods must be developed to enable the manager to control and eliminate the threats to the species.

31. Develop methods to control introduced plants.

Based on the results of Task #21, methods must be developed to control alien plants. Methods should consider the xeric environment at PTA which is prone to erosion and fire. Selective herbicides or pulling noxious plants by hand, may be effective means of weed control in these areas.

32. Develop methods to control introduced birds.

Based on the results of Task #22, methods must be developed to control alien birds.

33. Develop methods to control introduced insects.

Based on the results of Task #23, methods must be developed to control introduced insects.

34. Develop methods to control diseases.

Based on the results of Task #24, methods must be developed to control diseases.

35. Develop methods to limit the impacts of military activities.

Based on the results of Task #25, methods must be developed to limit the impacts of military activities.

4. Control feral animal populations.

Feral goats, sheep, and pigs are known to inhabit the Pohakuloa area. All of these species browse and graze native plant species, and should be controlled to some extent. However, feral pigs pose the most serious threat to the survival of H. haplostachya and S. angustifolia; a pig control program should, therefore, be actively pursued. Feral pigs are known threats to native ecosystems in general. In particular, pigs root up and consume native plants, creating wallows and spaces for introduced plants to colonize. In addition, the wallows provide breeding places for introduced mosquitos, the vectors for avian malaria and avian pox viruses. The survival of native plant species is thereby further jeopardized by threatening potential pollination vectors, such as native Hawaiian Honeycreepers.

Fencing populations aids in short-term recovery of species, by providing shelter from predators and other disturbances. However, the species cannot be considered to be fully recovered until such threats to their survival are eliminated, or at least controlled to such an extent that they no longer can be considered to be serious threats to the growth and reproduction of the species.

41. Assess the level of feral animal damage at Waikoloa.

The status of feral animals at the Waikoloa site has not been documented, and needs to be investigated. However, feral animals, especially pigs, are widespread in upland regions of all the main Hawaiian islands. The threat to native species, therefore, is expected to be significant at this site.

42. Assess the level of feral animal damage at Puu Anahulu.

See narrative for Task #41.

43. Allow unlimited hunting.

Unlimited hunting should be allowed to keep all feral animal populations down, minimizing the damage to the wild plants. However, hunters may also trample plants, so access to areas actually housing populations, and other sensitive areas, should be restricted.

44. Develop and implement methods of pig control.

The complete recovery of these species and many others, depend on successful control of feral pig populations. Species cannot be considered to be fully recovered until all wild populations are able to survive and reproduce unfenced, and removal of fences is not feasible until the threat of feral pig damage is eliminated.

Methods for pig control should be designed and implemented. For example, methods might include mark and recapture programs in order to estimate sizes of pig populations and to keep some record on the effectiveness of control programs.

5. Conduct surveys to locate all undiscovered populations.

An important step in the Haplostachys haplostachya and Stenogyne angustifolia recovery effort is the identification of new populations. New populations may increase the genetic variability of the species, and provide additional propagules for establishing new, genetically diverse populations. Additional wild populations will also help alleviate the risk of stochastic extinction due to the currently limited range of both species, but particularly for H. haplostachya. If additional populations are found, it will be necessary to

append the recovery plan to include measures for protecting these new populations.

51. Conduct surveys to locate populations of H. haplostachya.

A systematic survey for new populations should be planned and executed. There does not appear to be a specific habitat type required by H. haplostachya; the species has been collected from a diverse range of habitats. Therefore, highest priority should be given to an extensive survey of the grounds of PTA. In addition, the locations and surrounding areas where prior collections were made should be thoroughly investigated.

52. Conduct surveys to locate populations of S. angustifolia.

See narrative for Task #51.

6. Secure and stabilize newly discovered populations of H. haplostachya and S. angustifolia.

It is important to secure the habitat of any wild populations that are discovered through negotiations with the landowners and development of conservation easements, cooperative agreements, leases, or fee purchases.

61. Enter into long-term agreements with land owners to secure and manage any newly discovered populations.

Steps should be taken to secure new populations via long-term easement, cooperative agreement, lease or fee purchase between the landowner, the Service, and DOFAW.

62. Construct fenced exclosures.

See narrative for Task #14.

63. Control threats to any newly discovered populations.

See narrative for Task #15.

631. Maintain fenced exclosures.

See narrative for Task #151.

632. Control alien plants.

See narrative for Task #153.

633. Control introduced birds.

See narrative for Task #154.

634. Control insect predators.

See narrative for Task #155.

635. Control diseases.

See narrative for Task #156.

7. Develop and implement plans to augment the extant population, and create new populations.

All the known extant populations of H. haplostachya and all but two populations of S. angustifolia are located at PTA. Although protected habitat exists at PTA, approximately one-third of the populations of H. haplostachya, and one-half of the populations of S. angustifolia, are situated outside of the EPH and are therefore vulnerable to disturbance, largely as a result of military training activities. Fire, as a result of live ordinance detonations threatens all of the populations at PTA.

In addition, the close proximity of the populations increases the likelihood of the stochastic extinction of H. haplostachya due to a single environmentally catastrophic event. Although two populations of S. angustifolia are situated away from PTA and may escape extinction in the event of some stochastic phenomenon, the genetic variability of the species would be greatly reduced, thereby reducing the likelihood of full recovery. In addition, all known populations of S. angustifolia are in the Northwestern part of the island, so it is possible that a severe environmental catastrophe could cause the wholesale extinction of both species.

New populations must be established in more protected, stable habitats. In addition, the sizes of the existing populations must be increased, in order to optimize genetic diversity and prevent loss of the genetic integrity at both the population and species levels.

71. Conduct basic research on the genetic variability of extant plants.

The genetic variability within this species must be ascertained before outplanting or establishment of new populations can occur.

72. Develop appropriate propagation techniques.

Techniques for successfully propagating the species must be developed in order to ensure the preservation of the genetic integrity of the species. Attempts to germinate both H. haplostachya and S. angustifolia seeds have been relatively unsuccessful. Although treatment of the seedcoat improved the results, germination rates remain low. Vegetative cloning is another possible means of securing propagules for outplanting.

721. Establish propagule banks.

In order to reduce the loss of genetic vigor and quality caused by drastic population declines, a reservoir of propagules should be established. This reservoir will be used in the establishment of new colonies, as well as in the augmentation of existing populations. Meticulous records of propagule lineages (seeds and vegetative clones) are essential.

722. Develop standards for optimum production of propagules.

The propagation of healthy, viable propagules is essential to the recovery of the species. A qualified grower must be selected, and a protocol for producing quality propagules should be established.

723. Determine impacts of harvesting propagules.

Possible impacts of seed collection or removal of vegetative clones from natural populations must be closely monitored to detect any effect the harvest may have on the source populations.

724. Develop criteria for storage of propagules.

Proper cleaning, handling, and storage techniques must be developed to ensure the maximum viability of propagules. Storage of the propagules must be done in a manner that will maintain the genetic integrity of the species.

73. Select genetic stock to use in augmenting existing populations and establishing new populations.

Populations should be augmented only with transplants which originated from that population, unless future research dictates otherwise. However, in order to optimize reproductive vigor, and to serve as a buffer against possible inbreeding depression in the original populations, new populations should be established from a genetically diverse stock. This program would still maintain the genetic "purity" of the original 14 populations of *H. haplostachya* and 9 populations of *S. angustifolia*, while allowing for the establishment of genetically diverse populations on Maui and Kauai.

74. Determine appropriate introduction techniques.

Plantings need to be carefully monitored and assessed to determine how to establish new populations. Transplantation methods, care after establishment, and other factors must be determined.

741. Determine optimal habitat requirements for growth and reproduction.

Basic information on the soil characteristics, temperature, light and moisture regimes that result in optimal growth and reproduction should be discerned and incorporated into management decisions.

742. Select specific areas for augmentation.

Once the genetic stock has been selected, specific areas within the exclosures must be identified as the precise anticipated location of all transplants (with a resolution of a few feet). Specific areas within existing exclosures should be carefully selected to receive transplanted propagules. Locations should be chosen in a manner that will cause minimum disturbance to the wild individuals, while considering the optimal conditions required for growth of transplanted individuals.

75. Augment existing populations with transplanted individuals.

Once introduction techniques that will provide maximal chances for the species survival are developed, a protocol should be established and implemented. Propagules should be transplanted into selected areas within the exclosures that house the wild populations in order to amplify these populations as quickly and as efficiently as possible.

76. Locate potential habitat areas for additional populations.

The identification of proper sites for establishment efforts is extremely important. Selected sites must possess, as completely as possible, the characteristics determined by Task #741. Ideally, the sites should also permit ready access for demographic studies, seed collection, and other recovery activities. Preference should be given to sites which are located on State-owned lands.

761. Conduct surveys on Maui, Kauai, and Molokai.

In order to avoid the possibility of stochastic extinction, new populations should be established on other islands where distributions were previously reported. Priority should be given to surveying areas where previous collections were made.

762. Secure the potential habitat sites.

See narrative for Task #6.

7621. Enter into long-term agreements with land owners to secure and manage any newly established populations.

See narrative for Task #61.

77. Construct fenced exclosures.

Because rooting by pigs, grazing by other feral ungulates, and trampling by both feral animals and man are major concerns, areas designated as sites for the establishment of new populations of H. haplostachya and S. angustifolia must be fenced before introduction of propagules can begin.

78. Determine appropriate introduction strategy.

Once the new habitat areas have been secured, and fenced from feral animals and man, propagules should be planted into the new exclosures, using the protocols developed in Task #75.

781. Conduct surveys to identify specific sites for introduction.

See narrative for Task #742.

782. Transplant propagules into new habitat areas.

Propagules should be transplanted into selected areas within exclosures as quickly and as efficiently as possible.

79. Control threats to the newly established populations.

See narrative for Task #15.

791. Maintain fences.

See narrative for Task #151.

792. Control alien plants.

See narrative for Task #153.

793. Control alien birds.

See narrative for Task #154.

794. Control insect predators.

See narrative for Task #155.

795. Control diseases.

See narrative for Task #156.

8. Develop and maintain a detailed monitoring program.

Propagules gleaned from wild and cultivated individuals will form the backbone of any reintroduction, restoration, or augmentation plan. Careful records must be maintained on the fate and location of each cutting or seedling in botanical gardens and each plant in the wild.

81. Map, tag, and monitor all wild plants.

Each of the plants that make up the populations at Pohakuloa (including populations outside of PTA), Puu Anahulu and Waikoloa must be mapped, tagged and monitored on a regular basis. Each cutting that is taken from these populations should be identified as to its origin by tag number and date. Accurate records must then be maintained on the fate and location of each cutting in botanical gardens and on each wild plant and cultivar in the exclosure sites.

82. Map, tag, and monitor all transplanted plants.

All transplanted individuals must be mapped, tagged, and monitored in order to determine the success of the program. It is important to know the lineages of all transplants, so that in the event that some seedlings die, they can be replaced with genetically similar plants to ensure that the populations do not become dominated by a single lineage or genotype. Knowledge of the lineages of individual plants also allows for the selective culling of specific genetic stocks should research dictate a change in management philosophy.

9. Verify or determine the scientific validity of the recovery objectives.

In constructing a management strategy for the recovery of an endangered species, it is essential to consider the long ranging implications of the stated objectives in the recovery plan, and to assess the scientific validity of these objectives.

91. Determine the number of populations needed to ensure survival over the next 200 years.

It will be necessary to know whether the projected 17 populations of H. haplostachya, and 10 populations of S. angustifolia are adequate to safeguard against catastrophic events over the next 200 years.

92. Determine the number of individuals needed to ensure the long-term survival of each population.

It is of utmost importance that we determine the number of individuals needed to ensure the long-term survival of each population.

93. Determine the breeding system and susceptibility to inbreeding depression.

It is necessary to determine whether it is more appropriate to maintain genetic "purity", or if it would be expedient to inject diversity into these populations. The approach that will take precedence will depend on the results of research on the breeding system and susceptibility to inbreeding depression of both Haplostachys haplostachya and Stenogyne angustifolia.

94. Determine whether the hypothesized human-induced changes in climate will affect the populations.

Hypothesized human-induced changes in global climate may also impact on local climates and, thus, plant distributions. It would be prudent to hypothesize how these global climate changes might affect the long-term survival of existing H. haplostachya and S. angustifolia populations.

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III. IMPLEMENTATION SCHEDULE

The Implementation Schedule that follows outlines actions and estimated cost for the Haplostachys haplostachya and Stenogyne angustifolia recovery program, as set forth in this recovery plan. It is a guide for meeting the objectives discussed in Part II of this Plan. This schedule indicates task priority, task numbers, task descriptions, duration of tasks, the agencies responsible for committing funds, and lastly, estimated costs. The agencies responsible for committing funds are not, necessarily, the entities that will actually carry out the tasks. When more than one agency is listed as the responsible party, an asterisk is used to identify the lead entity.

The actions identified in the implementation schedule, when accomplished, should protect habitat for the species, stabilize the existing populations and increase the population sizes and numbers on Hawaii, Maui, Kauai, and/or Molokai. Monetary needs for all parties involved are identified to reach this point.

Priorities in Column 1 of the following implementation schedule are assigned as follows:

- Priority 1 - An action that must be taken to prevent extinction or to prevent the species from declining irreversibly.
- Priority 2 - An action that must be taken to prevent a significant decline in species population/habitat quality, or some other significant negative impact short of extinction.
- Priority 3 - All other actions necessary to provide for full recovery of the species.

Key to Acronyms Used in Implementation Schedule

- FWE - U.S. Fish and Wildlife Service, Ecological Services,
Honolulu, Hawaii
- DOFAW - Division of Forestry and Wildlife, Hawaii
Department of Land and Natural Resources
- RES - U.S. Fish and Wildlife Service, Research Division
- DOA - Department of the Army

Recovery Plan Implementation Schedule for Haplostachys haplostachya and Stenogyne angustifolia (THRU 1997)

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (YRS)	RESPONSE STABLE PARTY	TOTAL COST	COST ESTIMATES (\$1,000 PER FISCAL YEAR)					1997	Comments
						1993	1994	1995	1996			
1	111	Enter into long-term agreements to secure and manage the populations within the EPII at Pohakuloa.	2	FWE* DOFAW DOA	2 1 1	0.5 0.5 0.5	0.5 0.5 0.5					
1	112	Enter into long-term agreements to secure and manage the populations outside the EPII at Pohakuloa.	2	FWE* DOFAW DOA	2 1 1	1 0.5 0.5	1 0.5 0.5					
1	121	Conduct a thorough survey of Maikoloa.	1	DOFAW* FWE	15 10		15 10					
1	122	Enter into long-term agreements to secure and manage the populations at Maikoloa.	2	FWE* DOFAW	3 1		1.5 0.5		1.5 0.5			
1	131	Conduct a thorough survey of Puu Anahulu.	1	DOFAW* FWE	15 10		15 10					
1	132	Enter into long-term agreements to secure and manage the populations at Puu Anahulu.	1	FWE* DOFAW	3 1		1.5 0.5		1.5 0.5			
1	141	Construct a fence around the EPII.	2	DOFAW* DOA FWE	30 20 20		15 10 10		15 10 10			
1	142	Complete construction of fences around extant populations outside of the EPII at Pohakuloa.	2	DOFAW* DOA FWE	30 20 20			15 10 10		15 10 10		
1	143	Construct a fence around the Maikoloa populations.	1	DOFAW* FWE	25 20				25 20			
1	144	Construct a fence around the Puu Anahulu populations.	1	DOFAW* FWE	25 20				25 20			

Recovery Plan Implementation Schedule for *Haplostachys haplostachya* and *Stenogyne angustifolia* (TIIRU 1997)

PRIOR- ITY #	TASK #	TASK DESCRIPTION	TASK DURA- TION (YRS)	RESPON- SIBLE PARTY	TOTAL COST	COST ESTIMATES (\$1,000 PER FISCAL YEAR)					1997	Comments
						1993	1994	1995	1996			
1	151	Maintain fenced exclosures at Pohakuloa.	C	DOFAW* DOA FWE	4 3 3				11		4 3 3	
1	1521	Develop methods of controlling fire at Pohakuloa.	5	DOFAW* FWE DOA	28 16 16		7 4 4	7 4 4	7 4 4	7 4 4	7 4 4	
1	1522	Implement fire control plans.	C	DOFAW* DOA FWE	24 18 18				12 9 9		12 9 9	
1	153	Control alien plants.	C	DOFAW* FWE	25 25	5 5	5 5	5 5	5 5	5 5	5 5	
1	154	Control introduced birds.	C	DOFAW* FWE	15 15			5 5	5 5	5 5	5 5	
1	155	Control insect predators.	C	DOFAW* FWE	15 15			5 5	5 5	5 5	5 5	
1	156	Control diseases.	C	DOFAW* FWE	15 15			5 5	5 5	5 5	5 5	
1	157	Control military activities.	C	DOA* DOFAW FWE	18 6 6			6 2 2	6 2 2	6 2 2	6 2 2	
1	43	Allow unlimited hunting.	C	DOFAW* FWE	4 2		1 0.5	1 0.5	1 0.5	1 0.5	1 0.5	
1	44	Develop and implement methods of pig control.	C	DOFAW* FWE	24 21			8 7	8 7	8 7	8 7	
1	71	Conduct basic research on the genetic variability of extant plants.	C	FWE* DOFAW RES	36 32 32	13	114.5	155.5	240.5	121.5	9 8 8	

Recovery Plan Implementation Schedule for *Haplostachys haplostachya* and *Stenogyne angustifolia* (TIHRU 1997)

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (YRS)	RESPONSE-ABLE PARTY	TOTAL COST	COST ESTIMATES (\$1,000 PER FISCAL YEAR)					1997	Comments
						1993	1994	1995	1996	1997		
1	721	Establish propagule banks.	1	FWE* DOFAW RES	4 3 3		4 3 3		1			
1	722	Develop standards for optimum production of propagules.	5	FWE* DOFAW RES	16 12 12		4 3 3	4 3 3	4 3 3	4 3 3		
1	723	Determine impacts of harvesting propagules.	5	DOFAW* FWE RES	8 6 6		2 1.5 1.5	2 1.5 1.5	2 1.5 1.5	2 1.5 1.5		
1	724	Develop criteria for storage of propagules.	5	FWE* DOFAW RES	16 12 12		4 3 3	4 3 3	4 3 3	4 3 3		
1	73	Select genetic stock to use in augmenting existing populations and establishing new populations.	10	FWE* DOFAW RES	6 5 5					6 5 5		
1	741	Determine optimal habitat requirements for growth and reproduction.	10	FWE* DOFAW RES	20 15 15	4 3 3	4 3 3	4 3 3	4 3 3	4 3 3		
1	742	Select specific areas for augmentation.	10	DOFAW* FWE RES	2 1 1				1 0.5 0.5	1 0.5 0.5		
1	75	Augment existing populations with transplanted individuals.	10	DOFAW* FWE	2 1.5 1.5					2 1.5 1.5		
		NEED 2 (Augment extant populations)			285	10	70	60	62	83		
1	51	Conduct surveys to locate populations of <i>H. haplostachya</i> .	2	DOFAW* FWE	30 30	15 15	15 15					
1	52	Conduct surveys to locate populations of <i>A. angustifolia</i> .	2	DOFAW* FWE	30 30	15 15	15 15					

Recovery Plan Implementation Schedule for *Haplostachys haplostachya* and *Stenogyne angustifolia* (IHRU 1997)

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (YRS)	RESPONSE	TOTAL COST	COST ESTIMATES (\$1,000 PER FISCAL YEAR)				1997	Comments
						1993	1994	1995	1996		
1	61	Enter into long-term agreements with land owners to secure and manage newly discovered populations.	2	FUE* DOFAV	1			0.5	0.5		
1	62	Construct fenced exclosures.	2	DOFAV* FUE	25 20					25 20	
1	631	Maintain fenced exclosures.	C	DOFAV* FUE	0						
1	632	Control alien plants.	C	DOFAV* FUE	5					5	
1	633	Control introduced birds.	C	DOFAV* FUE	5					5	
1	634	Control insect predators.	C	DOFAV* FUE	5					5	
1	635	Control diseases.	C	DOFAV* FUE	5					5	
1	761	Conduct surveys on Maui, Kauai, and Molokai.	2	DOFAV* FUE	60 50			30 25	30 25		
1	7621	Enter into long-term agreements with land owners to secure and manage any newly established populations.	2	FUE* DOFAV	1 0.5					1 0.5	
1	77	Construct fenced exclosures.	2	DOFAV* FUE	0						
1	781	Conduct surveys to identify specific sites for introduction.	15	DOFAV* FUE	0						
1	782	Transplant propagules into new habitat areas.	15	DOFAV* FUE	0						

Recovery Plan Implementation Schedule for *Haplostachys haplostachya* and *Stenogyne angustifolia* (IHRL 1997)

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (YRS)	RESPONSE PARITY	TOTAL COST	COST ESTIMATES (\$1,000 PER FISCAL YEAR)					1997	Comments
						1993	1994	1995	1996			
1	791	Maintain fences.	C	DOFAW* FWE	0							
1	792	Control alien plants.	C	DOFAW* FWE	0							
1	793	Control alien birds.	C	DOFAW* FWE	0							
1	794	Control insect predators.	C	DOFAW* FWE	0							
1	795	Control diseases.	C	DOFAW* FWE	0							
		NEED 3 (Establish new populations)			319.5	60	60	56.5	56.5	86.5		
2	21	Determine the effects of introduced plants.	5	RES* FWE DOFAW	50 25 25	10 5 5	10 5 5	10 5 5	10 5 5	10 5 5		
2	22	Determine the effects of introduced birds on reproduction.	10	RES* FWE DOFAW	50 25 25	10 5 5	10 5 5	10 5 5	10 5 5	10 5 5		
2	23	Determine the effects of introduced insects.	5	RES* FWE DOFAW	50 25 25	10 5 5	10 5 5	10 5 5	10 5 5	10 5 5		
2	24	Determine the effects of diseases.	5	RES* FWE DOFAW	50 25 25	10 5 5	10 5 5	10 5 5	10 5 5	10 5 5		
2	25	Determine the effects of military activities.	10	RES* FWE DOFAW	20 15 15	4 3 3	4 3 3	4 3 3	4 3 3	4 3 3		
2	31	Develop methods to control introduced plants.	10	DOFAW* FWE	20 15	4 3	4 3	4 3	4 3	4 3		
2	32	Develop methods to control introduced birds.	10	DOFAW* FWE	20 15	4 3	4 3	4 3	4 3	4 3		
2	33	Develop methods to control introduced insects.	10	DOFAW* FWE	20 15	4 3	4 3	4 3	4 3	4 3		

Recovery Plan Implementation Schedule for *Haplostachys haplostachya* and *Stenogyne angustifolia* (THRU 1997)

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (YRS)	RESPONSE PARITY	TOTAL COST	COST ESTIMATES (\$1,000 PER FISCAL YEAR)					1997	Comments
						1993	1994	1995	1996	1997		
2	34	Develop methods to control diseases.	10	DOFAW*	20	4	4	4	4	4	4	
				FWE	15	3	3	3	3	3	3	
2	35	Develop methods to limit the impacts of military activity.	10	DOFAW*	20	4	4	4	4	4	4	
				FWE	15	3	3	3	3	3	3	
				DON	15	3	3	3	3	3	3	
2	41	Assess the level of feral animal damage at Weikotao.	2	DOFAW*	8				4	4	4	
				FWE	6				3	3	3	
2	42	Assess the level of feral animal damage at Puu Anahulu.	2	DOFAW*	8				4	4	4	
				FWE	6				3	3	3	
2	81	Map, tag, and monitor all wild plants.	C	DOFAW*	40	8	8	8	8	8	8	
				FWE	35	7	7	7	7	7	7	
2	82	Map, tag and monitor all transplanted plants.	C	DOFAW*	40	8	8	8	8	8	8	
				FWE	35	7	7	7	7	7	7	
		NEED 4 (Conduct research and monitor)			818	158	158	158	172	172		
3	91	Determine the number of populations needed to ensure survival over the next 200 years.	3	FWE*	24			8	8	8	8	
				DOFAW	21			7	7	7	7	
3	92	Determine the number of individuals needed to ensure the long-term survival of each population.	3	FWE*	24			8	8	8	8	
				DOFAW	21			7	7	7	7	
3	93	Determine the breeding system and susceptibility to inbreeding depression.	20	FWE*	40	8	8	8	8	8	8	
				DOFAW	35	7	7	7	7	7	7	
3	94	Determine whether the hypothesized human-induced changes in climate will affect the populations.	20	FWE*	9			3	3	3	3	
				DOFAW	6			2	2	2	2	
		NEED 5 (Validate recovery objectives)			180	15	15	50	50	50		
		TOTAL YEARLY COST			2247.5	256	417.5	480	581	513		